CHM111 General Chemistry I

Key

Thermochemistry Practice Problems

$= 2(N) + 4(H) + 3(O)$

$= 2(14.007\ g/mol) + 4(1.00794\ g/mol) + 3(15.9\ g/mol)$

$= 80.043\ g/mol$

1) Adding 5.44 g of NH_4NO_3 (s) to 150.0 g of water in a coffee-cup calorimeter (with stirring to dissolve the salt) results in a decrease in temperature from 18.6 °C to 16.2 °C. Calculate the enthalpy change for dissolving NH_4NO_3 in water, in kJ/mol. Assume the solution has a mass of 155.4 g and a specific heat capacity of 4.2 J/g•K.

Know

$NH_4NO_3(s)$ dissolving water

mass = 5.44 g

mass = 150.0 g

solution

$T_f = 16.2°C$

$T_i = 18.6°C$

$\Delta T = -2.4°C = -2.4\ K$

↳ recall, ΔT (in °C) = ΔT (in K)

mass = 155.4 g

$C_s = \frac{4.2\ J}{g \cdot K}$

Want ΔH for dissolving NH_4NO_3 in water

kJ/mol ← can determine using molar mass

↑ can determine from $q_{dissolving} = -q_{sol'n}$

Determine moles NH_4NO_3:

$5.44\ g\ NH_4NO_3 \times \frac{1\ mol\ NH_4NO_3}{80.043\ g} = 0.06796 = 0.0680\ mol\ NH_4NO_3$

Determine $q_{sol'n}$:

$q_{sol'n} = m_{soln}\ C_{s\ sol'n}\ \Delta T_{sol'n}$

$q_{sol'n} = (155.4\ g)\left(\frac{4.2\ J}{g \cdot K}\right)(-2.4\ K)$

$q_{sol'n} = 1566.4 = -1600\ J$

Determine $q_{dissolving}$ $= -q_{sol'n}$

$q_{dissolving} = +1600\ J$

$\Delta H = \frac{q_{dissolving}}{mol\ NH_4NO_3} = \frac{+1600\ J}{0.0680\ mol\ NH_4NO_3}$

$\Delta H = 23,529\ J/mol$

h ÷ by 1000 to convert to kJ

$\Delta H = 23.5 = \frac{24\ kJ}{mol\ NH_4NO_3}$

2) Suflur (2.56 g) is burned in a constant volume calorimeter with excess O_2 (g). The temperature increases from 21.25 °C to 26.72 °C. The bomb has an overall heat capacity of 4.33 kJ/K. Calculate the heat evolved, per mole of SO_2, for the reaction: **S_8 (s) + 8 O_2 (g) → 8 SO_2 (g).**

Know

Sulfur (S_8)

mass = 2.56 g

molar mass =

calorimeter

$T_f = 26.72°C$

$T_i = 21.25°C$

$\Delta T = 5.47°C = 5.47\ K$

$C = \frac{4.33\ kJ}{K}$ ← not not specific heat b/c no 'g'

Want heat of reaction = $q_{rxn} = \Delta H$ / mole SO_2 ← can determine from $q_{calorimeter} = -q_{rxn}$

↑ can determine using molar mass & molar ratios from balanced chemical equation

Determine moles SO_2

limiting reagent : excess

$2.56\ g\ S_8 \times \frac{1\ mol\ S_8}{256.528\ g} \times \frac{8\ mol\ SO_2}{1\ mol\ S_8} = 0.0798\ mol\ SO_2$

Determine q_{rxn}

$q_{rxn} = -q_{calorimeter} = -C\ \Delta T = -\left(\frac{4.33\ kJ}{K}\right)(5.47\ K)$

$q_{rxn} = -23.7\ kJ$

so $\Delta H = \frac{q_{rxn}}{mol\ SO_2}$

$= \frac{-23.7\ kJ}{0.0798\ mol\ SO_2}$

$\Delta H = -297\ kJ/mol\ SO_2$

↑ makes sense b/c rxn releasing heat so temp. of surroundings ↑

3) Determine the enthalpy change for the following reaction:

P_4 (s) + 6 Cl_2 (g) → 4 PCl_3 (l)

Given: step 1: P_4 (s) reactant + 10 Cl_2 (g) reactant → 4 PCl_5 (s) product $\Delta H = -1774.0$ kJ

step 2: PCl_3 (l) needs to be reactant + Cl_2 (g) → PCl_5 (s) $\Delta H = -123.8$ kJ

10 − 4 = 6

step 3: need to reverse rxn

$P_4(s) + 10\,Cl_2(g) \rightarrow 4\,PCl_5(s)$ $\Delta H = -1774.0$ kJ

$PCl_5(s) \rightarrow PCl_3(l) + Cl_2(g)$ $\Delta H = +123.8$ kJ (b/c reversed rxn)

step 4: need multiple

need ×4 to cancel & need 4 in product

$4\,PCl_5(s) \rightarrow 4\,PCl_3(l) + 4\,Cl_2(g)$ $\Delta H = 4(123.8\text{ kJ}) = +495.2$ kJ

step 5: sum: $P_4(s) + 6\,Cl_2(g) \rightarrow 4\,PCl_3$ ✓

step 6: $\Delta H_{rxn} = (-1774.0\text{ kJ}) + (+495.2\text{ kJ})$

$\Delta H_{rxn} = -1278.8$ kJ

4) The standard enthalpy of formation of solid barium oxide, BaO, is -553.5 kJ/mol, and the standard enthalpy of formation of barium peroxide, BaO_2, is -643.3 kJ/mol.

a) Calculate the standard enthalpy change for the following reaction:

know: $\Delta H_f^\circ = -643.3$ kJ/mol

$2\,BaO_2$ (s) → $2\,BaO$ (s) + O_2 (g)

$\Delta H_f^\circ = -553.5$ kJ/mol

Is the reaction endothermic or exothermic?

↳ so need to know $\Delta H_{rxn}^\circ = \Sigma \Delta H_f^\circ(\text{products}) - \Sigma \Delta H_f^\circ(\text{reactants})$

$\Delta H_{rxn}^\circ = [2(\Delta H_f^\circ BaO) + \Delta H_f^\circ O_2] - [2(\Delta H_f^\circ BaO_2)] = [2(-553.5\text{ kJ/mol}) - 0] - [2(-643.3\text{ kJ/mol})]$

O_2 element in its std. state: zero!

$\Delta H_{rxn}^\circ = [-1107\text{ kJ}] - [-1286.6\text{ kJ}] = +179.6$ kJ → endothermic

b) What is the heat associated the conversion of 125 g of BaO_2 into BaO?

know: BaO_2, mass = 125 g, 2 mol BaO_2 for $\Delta H_{rxn}^\circ = +179.6$ kJ

want: heat = q_{rxn} (kJ = units or J?)

$125\text{ g } BaO_2 \times \frac{1\text{ mol } BaO_2}{169.325\text{ g}} \times \frac{+179.6\text{ kJ}}{2\text{ mol } BaO_2} = +66.3$ kJ heat absorbed

rewritten: $\frac{\Delta H_{rxn}^\circ}{2\text{ mol } BaO_2} = \frac{+179.6\text{ kJ}}{2\text{ mol } BaO_2} = \frac{q_{rxn}}{2\text{ mol } BaO_2}$

molar mass = 1(Ba) + 2(O) = (137.327 g/mol) + (2 × 15.999 g/mol) = 169.325 g/mol

↳ so can use molar mass to convert g → mol